Circular No. 457
Issued April 1938
Revised December 1941 • Washington, D. C.
UNITED STATES DEPARTMENT OF AGRICULTURE

Mushroom Pests and Their Control

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CONTENTS

INTRODUCTION

The great increase in both commercial and amateur mushroom growing in the United States during the last 30 years has brought increasingly to the attention of the growers that cultivated mushrooms are subject to serious loss from improper cultural methods, diseases, fungus weeds, insects, and mites. In these days of relatively lower prices and higher production costs it is necessary that the grower obtain more mushrooms per square foot of bed space than ever before if he is to succeed, and in order to do this every possible source of loss must be eliminated. Studies by various agencies have partly solved most of these problems, but there still remains much to be done. This circular deals principally with the insects and mites that attack mushrooms and with their control. Especially in such districts as southeastern Pennsylvania, which produces more than 50 percent of the mushrooms grown in the United States, where some mushrooms are grown at all seasons of the year, and in which the industry is greatly concentrated, insect and mite pests are a constant menace.

Mushroom flies (Sciaridae), manure flies (Phoridae), the mushroom mite, and the long-legged mite are the most important pests of cultivated mushrooms in the United States. In addition to these, however, there are several other pests of lesser importance.

Extensive experiments have demonstrated that the control of mushroom insects and mites, after they have become established in the houses[1] is very difficult, owing to the extreme sensitiveness of the mushrooms to chemicals, and because the chemicals that have so far been in use and are known to be safe to use do not readily penetrate into the beds. Nevertheless, by means of sanitation, proper composting and heating, and fumigation, these pests can be reduced in numbers or entirely eliminated before the beds are spawned, and largely prevented from entering the houses thereafter.

This circular is designed to acquaint the grower with the principal mite and insect pests of mushrooms, their life histories in a general way, and the steps to be taken to prevent them from damaging the crop.

IMPORTANCE OF PROPER COMPOSTING FOR CONTROL OF MUSHROOM PESTS

Proper composting of manure for mushroom culture is an important factor in the control of mushroom pests. Composting is best done on a concrete floor. This prevents the entrance into the manure of many pests from the ground, and if there is a gutter around the edge that may be kept filled with water many fly maggots will be trapped and drowned therein as they leave the manure. Whether the composting is done on concrete or on the ground, the composting floor should be well scraped and cleaned, drenched with a solution of 1 gallon of formaldehyde to 50 gallons of water, and allowed to air for from 2 to 4 days before the manure is placed on it. Some people are much more sensitive to formaldehyde than others. Its use should not be attempted by persons unfamiliar with its qualities without securing expert advice.

At the first turning the manure should be well forked over, all lumps and cakes broken up, and straw added if necessary. The temperatures within the heap, except at ground level, are too high to allow insects and mites to survive, but both mites and insects can develop in the cooler outside layer of from 3 to 6 inches. The heap should therefore be kept well ricked up during the composting so as to expose as little surface as possible to attack. Along the ground level the temperatures are often under 100° F., oxygen is practically lacking, and the carbon dioxide concentration is very high. Under these conditions the manure may remain uncomposted until it is turned and thrown to the outside of the heap. This combination of low oxygen and high carbon dioxide concentration, while perhaps causing pests to become inactive, probably kills very few of them and does not prevent the entrance of others from the soil. It is important, in turning compost heaps, that the layer at ground level and that within 6 inches or so of the outside be thrown to the hottest part of the heap, not only to kill any insect or mite pests that may be present, but also to encourage more even and better composting. In an average compost heap this hottest area begins about 1 or 1½ feet from the side and bottom, and ends about 6 or 7 feet from the side and 6 to 10 inches from the top, as shown in figure 1.

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[1] The general term "mushroom house," as used in this circular, refers to any location where mushrooms are grown.

One of the principal difficulties confronting the amateur who contemplates growing mushrooms in small quantities in a cellar, barn, or other structure is that of properly composting small quantities of manure. This procedure is intimately related to the control of mushroom pests. Severe infestations of flies, mites, and springtails may result from the carriage of eggs and larvae into the beds with the compost, unless the compost is in proper condition to go through a good secondary fermentation or "heat" in the beds, to raise the

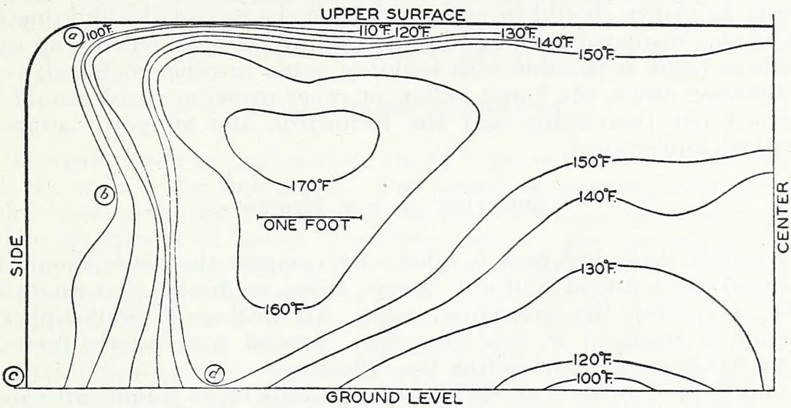


FIGURE 1.—Cross section through compost heap 4 feet high, showing temperature contours. Warm air rising at *a* draws in colder air at *c*, causing the convexity at *b*. The extension of the hotter region toward *d* is probably due to oxygen brought in by the fresh air. (Lambert and Davis.)

temperature to a point where insects and mites are killed. A half ton of manure of average quality is sufficient for from 35 to 45 square feet of mushroom bed, and it is extremely difficult to obtain proper composting of less than this quantity. One of the advantages of growing mushrooms on a small scale is the practicability of screening the small compost heaps with a cheesecloth to exclude insects; another is the ease with which a small composting floor of concrete or of 2- by 12-inch planks may be constructed, thus preventing the entrance of insects from the soil.

PRECAUTIONS TO BE OBSERVED IN PREPARATION OF THE MUSHROOM HOUSE OR CELLAR

Mushrooms are grown commercially in specially constructed houses, in various old buildings made over for the purpose, and in caves and mine galleries. Amateur growers ordinarily make use of basements or sheds. In buildings, raised beds in tiers are generally used. A space of from 6 inches to 1 foot should be left between the floor and the bottom of the lowest bed. This permits the bottom bed to heat better and facilitates proper cleaning of the floor. It also allows space for the circulation of fumigants, which is highly essential in pest control. In caves and mine galleries the mushroom beds are usually built on the floor and are referred to as "ground beds." They cannot be heated or fumigated properly and are therefore very dif-

ficult to free from insect pests after these have become established. Special care should be exercised to prevent the entrance of pests into such places. In recent years a few growers in the United States have been placing the composted manure in trays, which are then put through a heat and fumigation in special rooms before being carried into the caves or other growing rooms. Small crops grown by amateurs in cellars and other suitable places about their homes are particularly susceptible to insect attack, as these places are seldom capable of being properly fumigated. The room where mushrooms are to be grown should be separated from the rest of the building by partitions insulated with sawdust or cork if possible, but in any case made as tight as possible with building paper or other material.

Between crops, the house, cellar, or other growing space should be cleaned out thoroughly and the bedboards and supports scraped, brushed, and washed.

Spraying of the House

About 2 weeks before it is filled with compost the house should be sprayed inside to rid it of any insects, mites, or disease that might be left over from the preceding crop. All bedboards and supports should be included in this spraying. Several sprays have been in use for this purpose, including the following:

(1) Copper sulfate, at the rate of 6 pounds to 50 gallons of water.

(2) Calcium hypochlorite, at the rate of 10 ounces to 50 gallons of water.

(3) Mercuric chloride, at the rate of 8 standard tablets to the gallon of water or ½ pound of crystals to 50 gallons of water.

(4) Formaldehyde, at the rate of 2 gallons to 50 gallons of water.

(5) Lime-sulfur, at the rate of 1 gallon of boiled lime-sulfur to 10 gallons of water.

All these combinations are poisonous. Detailed safety instructions for their safe handling should be secured from your State Department of Agriculture or representatives of this Department before their use is attempted.

The best general-purpose spray for mushroom houses is the boiled lime-sulfur, since this spray is an insecticide as well as a fungicide and bactericide, which is not true of most of the materials mentioned above.

In caves, and in some mine galleries where there is no danger of setting the wooden bracing afire, flame throwers have been successfully substituted for sprays. The beds are first cleaned out, all loose spent compost is swept up, and the flame is played over the walls, ceiling, and floor, raising the temperature of these high enough to preclude any possibility of insect survival.

Fumigation or Sterilization of the House Before Filling It

Immediately before the compost is brought in, the house should, if possible, be fumigated with either formaldehyde or sulfur, or it should be sterilized by heating. In caves, owing to poor ventilation and ground beds, and in cellars, owing to the possibility of the gas escaping, it is not always possible to do this. Formaldehyde is a good

germicide and fungicide, but the gas from burning sulfur is about as good, and is also a useful insecticide, and is specific for mites. Before the house or room is fumigated or sterilized it should be made as airtight as possible by tightly closing all ventilators and other openings and by pasting paper or plastering mud over all cracks.

In cellars and other places close to dwellings it is not advisable to use sulfur or other materials as fumigants, unless such places can be sealed tightly enough to prevent all fumes from escaping. These vapors and fumes are poisonous to human beings. Sulfur should not be used where there is any possibility of the fumes reaching mushroom beds in production, as the growing mushrooms will be damaged.

FORMALDEHYDE FUMIGATION

Formaldehyde is used at the rate of 1 quart to 1,000 cubic feet of the air space to be fumigated. One pound of permanganate of potash is used to the quart of formaldehyde. Crocks, wooden buckets, or other containers of about 10-gallon capacity are needed, each of which will take care of 1 gallon of formaldehyde. Four pounds of the permanganate is placed in each of these, and a gallon of the formaldehyde in a wide-mouthed container beside it. Starting at the end of the house farthest from the door, the operator pours the formaldehyde into the containers with the permanganate as he moves toward the door, and leaves the house or room at once, closing and sealing it. The reverse of this procedure, dropping the permanganate into the containers containing the formaldehyde, is sometimes the easiest method. Do not attempt to re-enter the room without wearing a suitable gas mask, until it is thoroughly ventilated. The use of a gas mask while the chemicals are being mixed would insure safety, particularly to people who are sensitive to these poisons. It would also prevent danger from splashing.

SULFUR FUMIGATION

In sulfur fumigation, a good grade of flowers of sulfur should be used at the rate of 5 or 6 pounds per 1,000 cubic feet of air space to be fumigated. It is most commonly burned in pans or metal trays with the edges high enough to prevent the molten sulfur from flowing over the edge and setting fire to the house, or in oil drums cut in half lengthwise. A little excelsior or crumpled paper is placed along the bottom of four or five pans, and the sulfur is poured along each side of it. Some growers prefer to use less sulfur per pan, covering the bottom of each tray with an inch layer of excelsior and sifting the sulfur over this. Still another method is to put excelsior in the bottom of the container and over this to place a piece of coarse screen, cover the screen with a piece of newspaper, and pour the sulfur on this. The use of a larger pan containing water, into which the smaller one containing the sulfur is placed, is an effective aid in preventing fire and accidents. In houses having dirt floors, pits may be dug therein and the sulfur burned as in the pans. **Sulfur should not be burned on concrete floors, as the heat is likely to cause the concrete to crack and buckle, thus throwing the burning sulfur about and setting fire to the house.**

In any method the important thing is to get as complete combustion in as short a time as possible. Recent experiments have shown that it is very unusual to get complete combustion by any method of burning sulfur within the houses, and that the time required for burning averages about 3 hours. In burning sulfur within the houses a uniform concentration is rarely if ever obtained, as the hot sulfur dioxide gas from the pans rises to the top of the house. By the time the gas has cooled sufficiently to settle to the floor the total concentration of sulfur dioxide gas within the house has reached a point too low to be of much value. There is also considerable hazard of fire and danger to human beings in burning sulfur within the houses by the methods now commonly used.

AN EFFECTIVE DEVICE FOR BURNING SULFUR

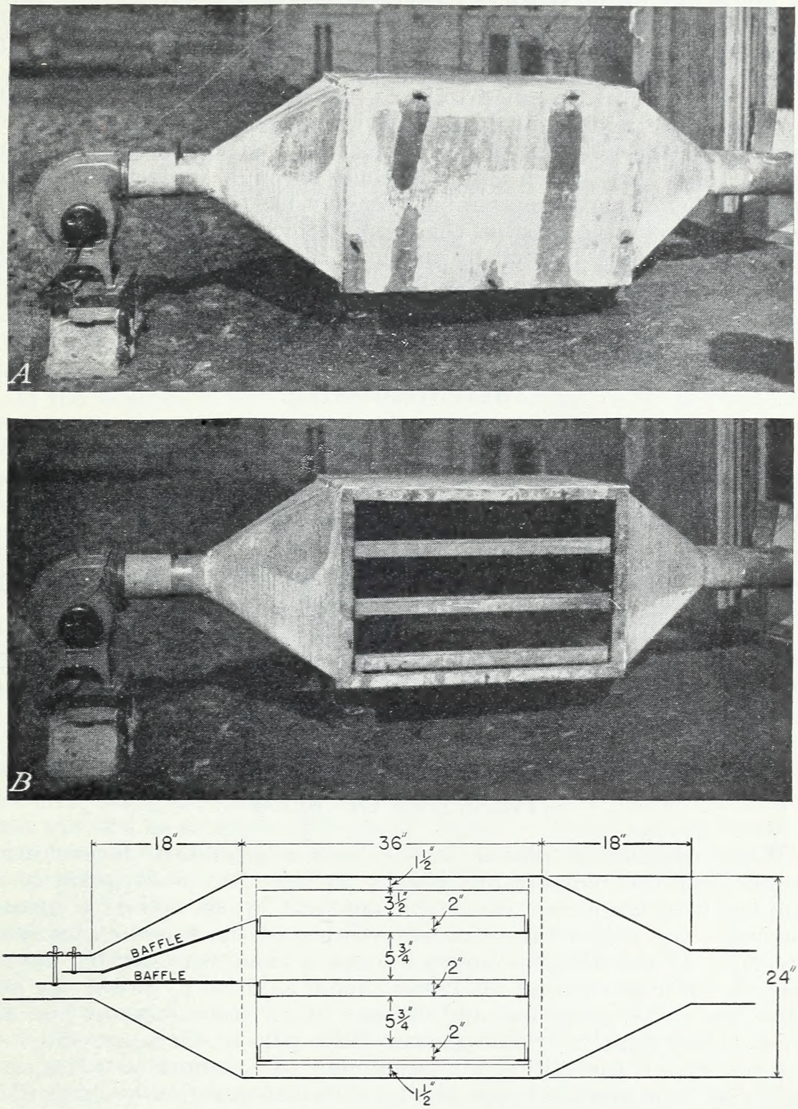
The use of the sulfur burner described below has been found by experimentation to be an improvement over the methods now in common use for fumigating mushroom houses with sulfur. It produces a highly concentrated gas in the house with less than one-third of the quantity of sulfur required by the pan method, burns the sulfur completely within about 30 minutes, reduces the fire hazard, and gives completely uniform distribution of the gas within the house. The details of construction are shown in figure 2, *C*.

The apparatus consists of a rectangular box 2 feet square and 3 feet long, of 18-gage galvanized sheet iron on a frame of 1½-inch angle iron. At each end is a cone 18 inches long, terminating in an open pipe, the intake pipe being 5 inches and the outlet pipe 6 inches in diameter. Within the box, sliding on supports of 1½-inch angle iron riveted to the frame, are three trays, each 23 by 34½ by 2 inches, and each capable of holding about 15 pounds of sulfur. The sides of the trays are strengthened by pieces of 1½-inch strap iron, and a piece of the same material is run from these crosswise beneath the center of each pan to prevent sagging. The door at the side is secured by bolts and wing nuts. To prevent the gas from escaping, a gasket of asbestos cloth is placed between the door and the body of the burner. All seams and connections are strongly crimped or riveted, as the heat of the burning sulfur will quickly melt any solder work.

In preliminary tests it was found that the sulfur in the middle tray burned faster than that in the top and bottom trays, owing to uneven distribution of air. This condition was corrected by using baffles in the intake funnel. The baffles are of 18-gage galvanized sheet iron cut to fit the intake cone, with a piece of 3/32- by 1¼-inch strap iron riveted to the center of each, longitudinally. The ends of the strap iron are pierced with holes and project into the intake pipe, being held in place by bolts, the nuts of which are outside on top of the intake pipe (fig. 2, *C*), to allow adjustment of the baffles. The bases of the baffles rest on the tray supports. The spacing of the baffles must be determined by testing, or by the use of an anemometer, so that each pan receives air at the same rate.

The fan used is of the centrifugal type in a steel housing, connected directly to a 1/20 horsepower electric motor running at 1,750 revolutions per minute, and with a horizontal 5-inch discharge and 6-inch single suction. This fan delivers 150 cubic feet of air per minute. Since the outlet from the burner is an inch greater in diameter than

the intake, there is practically free delivery of air. In use, the fan is connected to the intake, and stovepipe is led from the delivery pipe into the house through an asbestos-lined opening in a false door made



C

FIGURE 2.—*A*, Outside sulfur burner in operation, with door closed and fan connected; *B*, the same with door open showing arrangement of pans; *C*, diagram showing details of construction.

of wallboard. It is advisable to extend the outlet, by means of several extra lengths of stove-pipe, so that the delivery of gas will be along the floor in the central alleyway. This gives slightly better

distribution of gas and also muzzles any flame that might otherwise be forced into the house.

The fumes from the sulfur did not cause appreciable corrosion of the galvanized metal, of which the greater part of the burner is composed, during the 3 years that it was in use. The iron frame has corroded to a slight extent, but the burner will probably last for a long time under ordinary conditions.

The burner was designed to burn 32 pounds of flowers of sulfur, this being the maximum dosage allowable in a standard mushroom house of 16,000 cubic feet when at peak heat. With this dosage, flame has at times been blown into the house through 10 feet or more of pipe. When using the maximum dosage it has therefore been thought best to cut down the speed of the fan by attaching one or two electric-light bulbs to the line or by using a rheostat. By increasing the length of lead-in pipe to 20 or 30 feet the same result might be obtained, together with a cooling of the fumes. In empty houses excellent fumigations have been obtained with as little as 20 pounds of flowers of sulfur.

HEAT STERILIZATION

In small spaces and where facilities are available, heat alone may be used for the eradication of mushroom pests before the house is filled. The source of the heat may be steam, or it may be electricity if the current is very cheap. A temperature of 120° to 125° F., if maintained for a few hours, should effectively rid the room of all insect and mite pests. A 16-inch electric fan with the blades directed upward at an angle of 45° should be kept running during this time to distribute the air evenly, otherwise the top of the space will be very hot and the air for a few inches above the floor will not be hot enough to kill the insects and mites. The room should be as dry as possible during this heating period.

PEST CONTROL DURING PROCESS OF FILLING AND HEATING OF BEDS

When compost is placed in the beds a secondary fermentation occurs and the temperature begins to rise. A small quantity of manure in a large cool place will not heat up so well as a greater quantity, nor will it raise the temperature of the surrounding space greatly. If the filling occupies too much time, considerable heat is wasted. For this reason the house should be filled as quickly as possible, the aisles swept out and cleaned of all loose manure, and the doors closed tightly. Some growers fill a part of the house and wait several days before filling the remainder. If manure is scarce, it is better to form storage heaps until a sufficient quantity is obtained to fill the house in one operation.

Natural and Artificial Heating

It is most important that a good heat be obtained in the compost at the time the house is filled because heat is the mushroom grower's cheapest and best method of combating insects and other closely related pests, as well as being necessary to "sweat out" the manure and put it in

the best condition for the spawn to "run." An ideal condition is to have the bottom beds at a temperature above 120° F. and the top beds below 140°. Recent experiments have shown that the ideal "heat" is from 130° to 135° for 7 or 8 days, but the usual mushroom house has not sufficient heating capacity to maintain this temperature after the compost itself begins to cool. At temperatures above 120° all forms of insect and mite pests will either be killed or driven to the surface of the beds, where they can be reached with fumigants.

Since ground beds are very difficult to heat properly, the insect and mite pests contained therein cannot be driven to the surface or killed by heat, and, since the fumigants in use at present do not penetrate the compost more than an inch or so, the pests present in such locations will survive and reinfest the house. Consequently, if the ground beds cannot be raised 4 or 6 inches from the floor to allow circulation of heated air beneath, it is better to abandon them entirely. The temperature of the bottom beds will usually lag about 10° F. behind that of the top ones, and air temperature will usually be 15° or 20° less on the floor than under the ceiling.

If the weather is very cool at the time of filling, or, as is frequently the case in amateur mushroom culture, the quantity of manure is too small and the insulation insufficient to allow the temperature to rise, the house may be heated artificially. Where steam or hot-water heat is not available, kerosene or oil burners have been used with success, but the use of oil heaters should usually be avoided, as oil fumes sometimes have a harmful effect on mushroom growth. Care must be taken that the beds do not dry out too much while this is being done.

Because the lower beds are filled first and lose much of their latent heat, and also because the warm air naturally rises to the top of the house, the tops beds heat faster and attain a higher temperature than the bottom ones. A more even distribution of heat may be obtained by the use of some method of forced air circulation. Where electric current is available the best method is to place two or three 16-inch electric fans in the central alleyway. Most growers place the fans on the floor along the center of the house, adjusted to direct the air current upward at an angle of from 45° to 80°. Better results, however, have been obtained by placing the fans on supports resting on the top beds, with the air current directed straight down. By this means the heated air in the top of the house is driven to the floor and is forced to circulate over the bottom beds before again rising to the top of the house. When the top beds have reached a temperature ranging from 120° to 130° F. the fans should be started and run for 5 or 6 hours, shut off to cool for 2 or 3 hours, and then run for another 5 or 6 hours.

To keep a check on the conditions during the heating process, accurate thermometers should be inserted into the top and bottom beds and hung in the central alleyway at the top and bottom of the house. Judging from preliminary results of experiments now being conducted, it seems fairly safe to state that an air temperature ranging from 120° to 125° F. if maintained for a few hours, and if evenly distributed through the room, will kill all insects and mites harmful to mushrooms. Such temperatures on the floor of the house and just above the floor are difficult to maintain, consequently fumigation is necessary. The manure in the beds will reach a much higher temperature during this time but should not be allowed to exceed 145°.

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A temperature of 120° for 48 hours will eradicate the "bubble" disease (mycogone) also.

During the heating of the compost in the beds much moisture is driven off. In basements of dwellings it is inadvisable to try to reach a high temperature unless the room can be sealed tightly enough to prevent the moisture and heat from warping the floor above.

Fumigation

When the temperature of the beds has reached its maximum the house should be fumigated with either sulfur or cyanide.

SULFUR

Sulfur should be burned at the rate of 1½ to 2 pounds per 1,000 cubic feet of air space. The amount used per 1,000 cubic feet, however, should not exceed 2 pounds. Within 5 or 6 hours after the sulfur has finished burning, the ventilators should be opened, the house allowed to air out, and then closed again to prevent too rapid cooling. Owing to the slow rate of burning and the rapid absorption of gas by the moisture in the house, it is doubtful whether an efficient fumigation is ever attained by burning sulfur in pans within the house at peak heat. The outside burner previously described (p. 6) will give much better results.

Sulfur fumigation has a tendency to raise the acidity of the first one-half inch or so of the beds (the limit of penetration of the gas), and a green mold often follows. This soon disappears, however, and neither it nor the increased acidity of the surface of the beds seems to have any harmful effect upon subsequent mushroom growth.

When a house to be fumigated is immediately adjacent to another in production, every precaution should be taken to keep the fumes from reaching and damaging the growing mushrooms. The ventilators of the house in bearing should be open, and the house in heat should be fumigated only when there is no wind, or when the wind is blowing away from the house in bearing. In case of a double house, the other half of which is in bearing or spawned, it is better to use cyanide rather than to risk damage from sulfur fumes.

HYDROCYANIC ACID GAS

The materials in common use for hydrocyanic acid gas fumigation are (1) calcium cyanide, (2) sodium cyanide and sulfuric acid, and (3) liquid hydrocyanic acid.

Since the application of liquid hydrocyanic acid requires special equipment, as well as special training on the part of the operator, and since it gives little better results than sodium cyanide and acid, it may be left out of this discussion.

The use of granular calcium cyanide at the rate of 1 pound per 1,000 cubic feet of air space is at present the most common method for fumigating mushroom houses at peak heat. As hydrocyanic acid gas is readily absorbed by moisture, the house, although damp, should not be wet, with puddles of water standing in the alleyways, or much of the gas will be lost before it is fairly liberated. Experiments have shown that the maximum concentration of gas is reached in from

10 to 20 minutes after the cyanide is scattered. **In view of the deadly nature and the rapid evolution of this gas, every precaution should be taken against accidents. No one should be permitted to open calcium cyanide or scatter it without wearing an approved gas mask equipped with a canister especially designed for that gas.** In the case of a single house, the chemical should be scattered in the central alleyway as evenly and quickly as possible, beginning at the back of the house and working toward the door. Special care should be taken to see that the alleyway is clear of obstructions before the fumigation is begun, as a stumble over some obstacle while walking backward and scattering the cyanide might easily result fatally, even though the workers are wearing gas masks. In the case of a double house the material is scattered in the two main alleyways, the workers starting together at the far end and working toward the doors, timing themselves so as to reach the doors simultaneously. After the operators have left the house the doors should be closed and tightly sealed and left so for about 12 hours.

Small fertilizer spreaders such as are used for distributing commercial fertilizer on lawns, when properly set, will give a more even and rapid distribution of calcium cyanide, and a higher concentration of gas than can be obtaining by hand scattering.

Caution: When entering a house after it has been fumigated, use a gas mask until the house has been thoroughly aired out.

The same precautions are necessary as with sulfur to prevent fumes from reaching and damaging growing mushrooms, although this gas is not so harmful to them as sulfur fumes. In the case of a double house, the other half of which is in bearing, the doors between them should be made gas-tight, all cracks and openings in the partition tightly sealed, and the doors and ventilators of the house in bearing opened. As a further precaution, it is desirable to fumigate when the wind is blowing away from the house in bearing.

The so-called pot method of fumigation, in which sodium cyanide and sulfuric acid are used, is almost as easy and convenient as that with calcium cyanide, and gives a more rapid liberation of gas and a much higher concentration. The material should be used at the rate of not less than 8 ounces of sodium cyanide to 12 fluid ounces of a good grade (66° Baumé) of commercial sulfuric acid and 16 fluid ounces of water per 1,000 cubic feet of air space. Three or four 3-gallon glazed crocks may be used for generators. The necessary quantity of water is measured out and divided among these. They are then set at equal intervals in the central alleyway of the house. The acid is similarly measured out and the necessary quantity placed in a glass jar beside each generator. The sodium cyanide having been similarly weighed out (it can be obtained in ½-ounce or 1-ounce "eggs" to save this work), and the proper quantity for each jar having been put into a heavy brown-paper bag (the thickness of paper may be doubled for additional safety by using two bags, one inside the other, for each charge), the operator takes the twisted necks of the bags in his left hand, enters the house, and pours the acid into each generator as he reaches it. Having reached the back of the house, he then walks rapidly toward the door, dropping one of the bags of cyanide in each generator as he passes it. The acid requires a short time to eat through the paper bags, and the operator is

usually well outside the door before the first charge begins to generate gas. The doors should be closed and sealed at once.

As an extra precaution, a house that has been fumigated should not be entered, even by a person wearing a gas mask, until it has been thoroughly ventilated. Fumigation with hydrocyanic acid gas should be avoided during periods of cold weather, in order that the house may be properly ventilated after the fumigation without possible injury to the crop because of a rapid drop in temperature during the ventilation.

As the floor is always the coolest part of a house that is heating or at peak heat, it is here that insects and mites are most likely to survive the heat. With any method of fumigation it is therefore desirable that as much of the gas as possible be kept in the lower part of the house. Unless fans are kept running in the house at the time of fumigation, the gas, being hot as well as lighter than air, will rise to the top of the house. The best results have been obtained by raising the fans to the level of the fourth or fifth beds, about 5 or 6 feet or more from the floor. In the pot method the air blast from the fans should be directed straight down over each generator. This causes the gas to blow along the floor and between the lower beds. After 20 or 25 minutes the concentration becomes nearly uniform throughout the house, but for the first 20 minutes most of the gas is along the floor, where it is most needed. Unless fans are of the fully enclosed type, it is better to wait for about 10 minutes before turning them on, as there is a remote possibility of gas and air forming an explosive mixture which might be set off by a spark. In experimental fumigation of commercial mushroom houses it was demonstrated, by using chemically equivalent dosages of calcium cyanide and sodium cyanide with acid ($1:1\frac{1}{2}:2$),[2] that sodium cyanide and acid was much superior to calcium cyanide in the concentration of gas obtained and was about half as expensive per fumigation.

There are two or three types of generators using sodium cyanide and acid which, if properly used, are almost if not quite as effective as the pots, and have the additional advantage that the gas is generated outside the building and forced in, the operator being at all times in the open air.

Sodium cyanide is extremely poisonous, and great care should be exercised in handling it. It should be stored under lock and key where it is not accessible to children or careless persons. The same precautionary measures should be taken with the acid.

The same rules as to procedure and safety apply to fumigation at peak heat in cellars or other small spaces as apply during preparation for the crop. Hydrocyanic acid gas should not be used in or adjacent to dwellings at all, and sulfur only when there is no possibility of the fumes escaping. In these places it is better to depend on heat for mushroom-pest control at any time when the beds do not contain spawn.

GENERAL SANITARY MEASURES

After the house has been through the "heat" and has been properly fumigated, precaution should be taken to prevent reinfestation by insects and the other closely related pests already mentioned. Doors

[2] Some experimenters recommend 1 : 1.25 : 1.8.

and ventilators may be made fly-tight with cheesecloth, or, better, 30-mesh copper screen, if it is found possible to do so without interfering too much with ventilation. This prevents the entrance of flies and also of any mushroom mites or diseases that they may be carrying.

Control of individual species of pests is discussed under separate headings.

In passing from a house infested with mushroom pests to one not so infested, great care should be taken that no insects are carried on the person or clothing.

All stem butts and discarded mushrooms should be carried away and burned, or placed in a hole, then covered with quicklime or kerosene and a layer of earth. They should never be allowed to stand about the house.

When the house has finished bearing and is about to be cleaned out, it should be allowed to dry out thoroughly and be fumigated if possible. In any case, the spent compost should be hauled to some distance from the houses.

CONTROL OF MUSHROOM PESTS IN BEARING HOUSES

After the beds have been cased, the temperature should be kept rather low. For the best results it should be possible to maintain an air temperature ranging from 50° to 55° F. A temperature below 55° is more to be desired than one above that level, as the lower temperature seems to be favorable for mushroom growth and is low enough to retard materially the development of insect and other pests of mushrooms.

The purpose of the treatments and practices recommended in the preceding sections is to prevent the infestation of beds. To date no entirely satisfactory methods have been devised for the control of insects and mites in the beds after the beds have been spawned. The majority of the chemicals used for this purpose either do not penetrate the beds deeply enough or they have a harmful effect upon the spawn, which is very easily damaged.

PRINCIPAL PESTS ATTACKING MUSHROOMS AND METHODS FOR THEIR CONTROL

Pests in mushroom plantings may be roughly divided into four groups: Flies, mites, springtails, and miscellaneous pests.

Flies

All things considered, flies seem to be the most destructive insects attacking the mushroom crop. The injury consists of the feeding of the maggots on the spawn in the beds and the tunneling into the stems and caps of the mushrooms, rendering them unfit for use. No direct damage is done by the adult flies, but the indirect damage they cause in transporting mites and disease organisms from bed to bed and from house to house, while difficult to estimate, seems to be nearly if not quite as important.[3]

[3] Charles, Vera K., and Popenoe, C. H. Some mushroom diseases and their carriers. U. S. Dept. Agr. Cir. 27, 9 pp., illus. 1928.

Flies attacking cultivated mushrooms are of three general kinds, known as mushroom flies or fungus gnats, manure flies, and cecidomyiid flies. All these are normally scavengers, feeding on wild fungi, leaf mold, and other organic material, and are not unduly numerous. With the concentration of their natural food, however, as in a mushroom house, they are able to build up abnormal populations.

MUSHROOM FLIES OR FUNGUS GNATS

There are at least four species of sciarid flies (of the genus *Sciara*) that have been recorded as injuring cultivated mushrooms seriously in the United States. Probably the most common of these is *S. fenestralis* Zett. Others that have been noted as attacking mushrooms are *S. coprophila* Lintner, *S. multiseta* Felt, and *S. agraria* Felt. They are much alike in appearance, habits, and life history, and for practical purposes may be regarded as one species. Figure 3, *C*, shows a drawing of an adult fly. Sciarid flies are slender, with rather long legs and antennae. They usually carry their wings folded flat upon the back when walking or at rest. They are black or yellow black. The males have a pair of claspers at the apex of the abdomen.

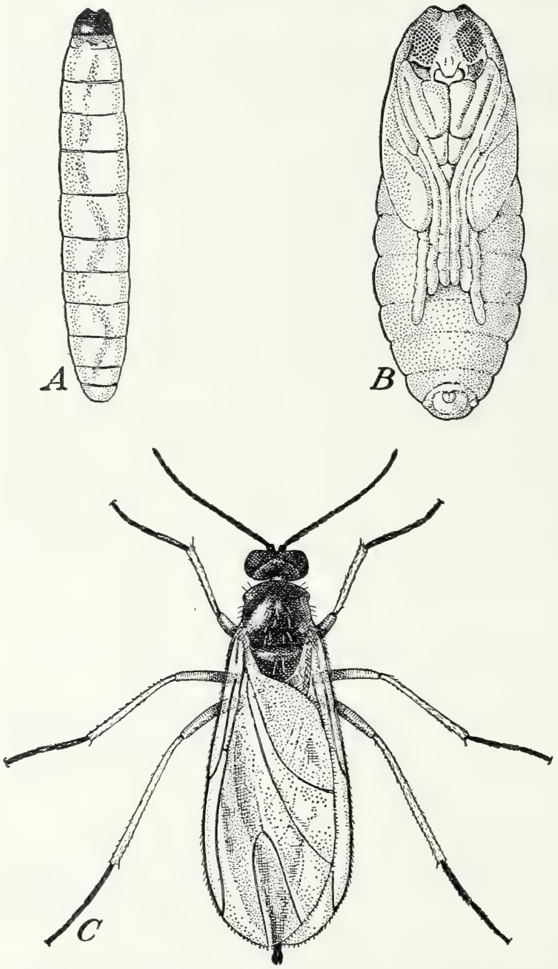

FIGURE 3.—Stages of a mushroom fly, *Sciara fenestralis*: *A*, larva, × 10; *B*, pupa, ventral view, × 15; *C*, adult, × 12.

The eggs (fig. 4) of these flies are very small, oval, white or yellowish. They are laid in the compost or spawn, in cracks in the casing soil, or upon the mushrooms. Under favorable conditions of temperature and humidity the egg hatches in 4 or 5 days into a legless white larva, or maggot, with a shiny, black head (fig. 3, *A*). After feeding for from

10 to 14 days the larva approaches the surface and spins a fragile silken cocoon, in which it transforms into a pupa (fig. 3, *B*). In 5 or 6 days the adult fly emerges, and it is capable of mating within a few hours. Females may commence oviposition within 24 hours. As each female is capable of laying from 200 to 300 eggs, and there is very little natural mortality among the larvae, it will be realized that the potential rate of increase is very great. As a rule, these flies are more common in the mushroom houses in winter than in fall or spring.

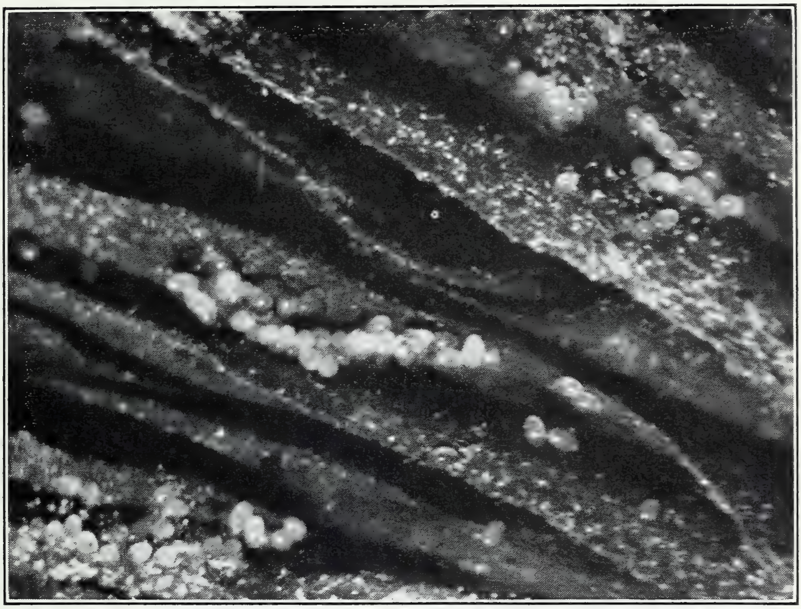

FIGURE 4.—Eggs of mushroom fly, *Sciara fenestralis*, × 16.

No effective method of combating the maggots of these flies within the beds is known. Control must be had through reducing the number of adult flies, thus decreasing the number of eggs laid. Traps and insecticides are the principal means of killing the adult flies.

TRAPS

Traps are of many varieties, but they all depend on light to attract the flies to them. They have been used with success, but they should be considered merely supplementary and not be depended on to the exclusion of dusting. The simplest type of trap is a pane of glass set into the south or east end of the house, usually in the door, about a foot or more above the floor. Fly paper or sticky treebanding material is placed about this to catch the flies as they come to the light, or a pan containing a little kerosene may be placed beneath it, into which the flies will fall and be killed. The pane of glass should not be too large, as the ends of the beds will then be too well illuminated and the female flies will often oviposit before they go to the glass, or they will not be attracted to the glass at all.

Experiments have shown that a glass pane of 72 square inches or less is most satisfactory for attracting flies to daylight.

Another type of trap is one in which the flies are attracted by an electric light, drawn in by a fan, and retained in a bag or jar. A trap of this type, used experimentally in a very heavily infested

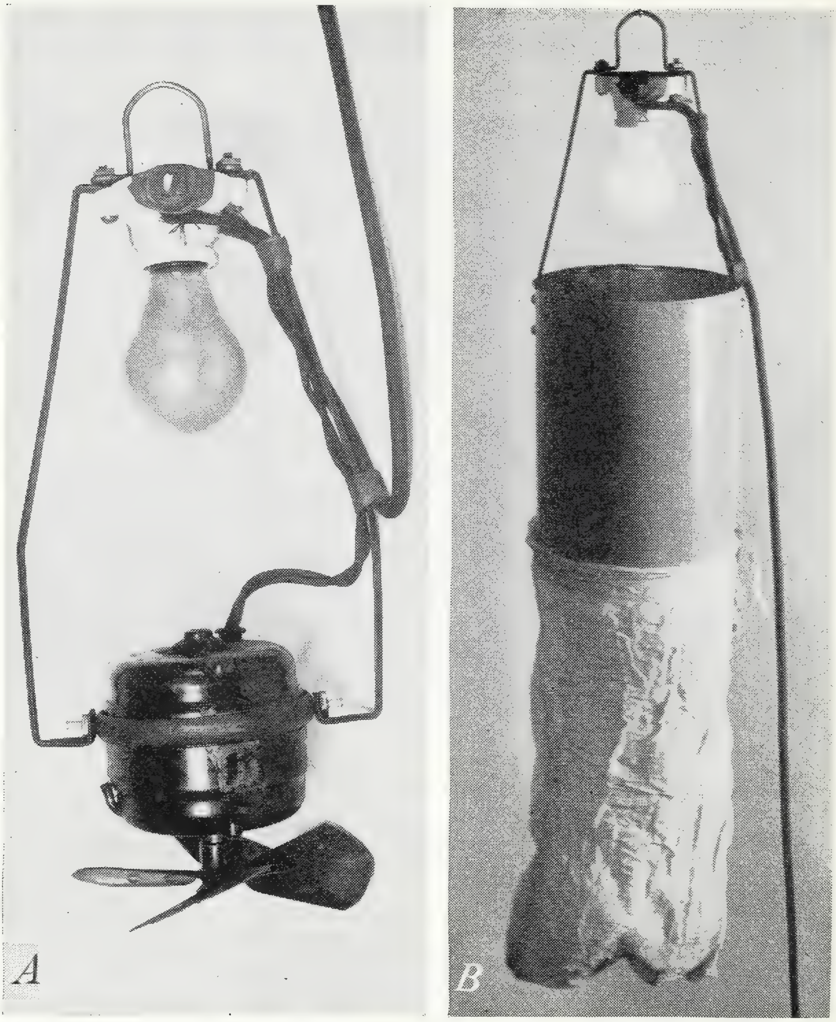

FIGURE 5.—Light-suction fly trap: *A*, frame showing position of fan; *B*, trap assembled.

house, caught over 187,000 flies in one 24-hour period, of which 75 percent were females, and more than half of these had not laid all their eggs. As in the case of traps depending on daylight to attract the flies, the illumination should not be too intense. A 40-watt white-frosted electric-light bulb has given most satisfactory results. If either the daylight or the artificial light used as a lure is not intense

enough the flies will not be attracted in great numbers, and if it is too intense they seem to be satisfied before they actually reach the trap and do not come any nearer to it.

A very simple and easily constructed light-suction trap of this type is shown in figure 5. The frame, shown in figure 6, is constructed of ½-inch strap iron, bent cold in an ordinary machinist's vise. All bolts used are $\frac{3}{16}$-inch stove bolts with the exception of the two that hold the motor ring to the rest of the frame, which are $\frac{3}{16}$-inch flat-headed bolts. The barrel is a 5-quart oil-can, such as can be obtained at any service station, with both ends removed. The fan motor should be adapted to operation in a vertical position, and should be fully enclosed to prevent the clogging of the armature with dead flies. A motor of this type, with the fan, costs about $7.

The trap can be constructed in about 30 minutes with the tools usually found about a home or farm workshop, at a total cost, with the exception of the motor, of around 35 cents.

In operation the trap is hung up by its wire loop, and a bag of light cheesecloth is tied to the bottom of the barrel with cord, the flange of the cap crimp preventing the cord from slipping off.

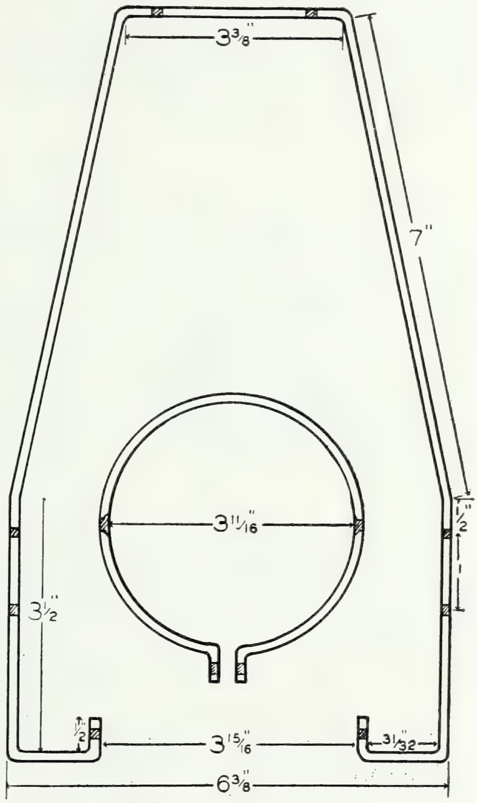

Figure 6.—Details of frame of light-suction trap.

INSECTICIDAL DUSTS

There are a number of insecticidal dust mixtures on the market that are used for mushroom fly control. A dust composed of 60 percent of pyrethrum, with 40 percent of finely ground diatomaceous earth or clay as a carrier, has been found satisfactory. The commercially prepared dusts vary in composition, but are usually based on this pyrethrum-carrier mixture, sometimes with other substances added. It is desirable to get as fine a dust as possible so that it will remain suspended in the air for a long time, and it is also well to get as light-colored a dust as possible, since darker dusts sometimes settle on the mushrooms and render them unsightly, thus decreasing their market value.

The house should be watched carefully, and as soon as a few flies appear it should be treated with the dust at the rate of 2 or 3 ounces per 1,000 cubic feet of air space. The majority of the growers dust two or three times a week. Before the house is dusted, the temperature should be allowed to reach 60° F. or more, then the dust should be applied, and the house should be left closed overnight. At any lower temperature the flies are less active and the dust is more inert. A good fan-type duster should be used and the dust thoroughly distributed throughout the house. If a duster is not available a good distribution may be obtained by shaking the dust slowly out of a bag into the air blast from an ordinary electric fan directed toward the ceiling of the house.

DRENCHES

Drenches of 2-percent alcoholic extract of pyrethrum used with water at the rate of 1 part to 800, applied to the beds at the rate of about 1 quart to 12 square feet, at weekly intervals, in place of the regular watering, and dichloroethyl ether at the rate of 3 cubic centimeters (roughly one-seventh of a liquid ounce, or three-fifths of a teaspoonful) per gallon of water, applied to the beds at the same rate, by means of a sprinkling can, have each given an increase in yield of about one-third of a pound per square foot of bed space. Pyrethrum kills few of the insects and mites, but acts as a repellent. It is probable that this is true of the dichloroethyl ether also.

FUMIGANTS

Fumigation with granular calcium cyanide at the rate of 1½ to 2 ounces per 1,000 cubic feet of air space has been used with some success for controlling adult mushroom flies. Its use will be discussed more fully under the following heading (p. 19).

MANURE FLIES

At least three species of phorid flies (of the genus (*Megaselia*) have been reported as doing commercial damage in mushroom plantings. These are *M. albidihalteris* Felt, *M. agarici* Lintner, and *M. iroquoiana* Malloch. As in the case of the mushroom flies, these three species of manure flies are so nearly alike in appearance and in their biology that they may be regarded as one species when their control is considered. They are frequently seen in immense numbers on and about the exterior of the houses. The adult flies (fig. 7) are black or blackish and usually slightly smaller than the sciarid flies. They are much more compactly built, the legs are stouter and not so long, and the head is rather small and the thorax large, giving them a humpbacked appearance. They are quite active, moving about constantly in a series of jerky runs.

The life history of these flies is known only in a general way. The time required by the various stages is dependent on conditions of temperature, humidity, and food, as is the case with the mushroom flies.

The eggs are very minute, white, and elongate-oval, and are laid in the compost or casing soil. They hatch in about 6 days, under

usual mushroom-house conditions. The larvae, or maggots, are shining white or yellowish, about one-fourth of an inch long when fully matured, legless, and without head capsules. After feeding for 10 days or more the maggots stop feeding and transform into yellowish pupae, appearing almost like small seeds. From these, after another interval, the adult flies emerge. Under ordinary conditions the time from egg to adult is about 28 days. Unlike the mushroom flies, the manure flies seem to require a period of flight before mating. Attempts to rear them in closed containers have been unsuccessful, although some have been reared in a cage containing about 36 cubic feet of space.

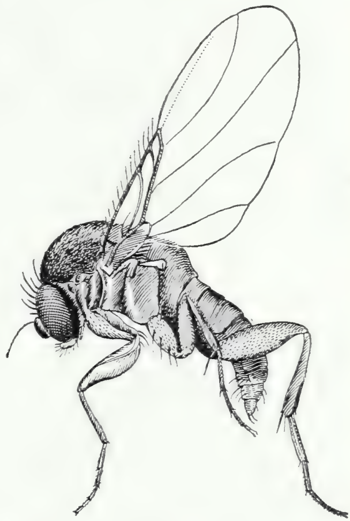

FIGURE 7.—An adult manure fly, *Megaselia albidihalteris*, × 18. (Popenoe.)

The infestation of mushroom beds by manure flies usually results from the introduction of larvae with compost that afterwards does not get sufficiently heated to kill them, or from eggs laid by adults that get into the house immediately after the heating. The damage is done by the larvae and is about the same as that described previously for the sciarid larvae, except that since the infestation by these pests occurs early in the development of the beds, the spawn may be prevented from running out from the spawn pieces, or the pieces themselves destroyed. The larvae also attack the growing mushrooms more readily than do the sciarid larvae. The greater part of the damage is done early in the season, usually becoming less noticeable after the beds are producing, although during the warm weather at the end of the spring crop much damage may be done to both spawn and growing mushrooms.

Control of manure flies is about the same as for mushroom flies, except that dusts must be used more liberally, the manure flies being more resistant to pyrethrum.

Granular calcium cyanide has been recommended for the control of both mushroom flies and manure flies in dosages of 1½ to 2 ounces per 1,000 cubic feet, and has proved successful in some cases, although in others severe damage to the mushrooms and a retardation of the spawn has been reported. Experiments have shown that, if carefully used, calcium cyanide in dosages up to 2¼ ounces per thousand cubic feet of air space does no harm to the mushrooms, and that even when repeated at weekly intervals throughout the crop growth no retardation of spawn results. It is very difficult to so regulate conditions in the average mushroom house that moisture, temperature, and humidity can be exactly duplicated from one fumigation to another. Under commercial conditions this will usually be a matter of guesswork, and will therefore vary greatly. Since moisture and humidity largely govern the rate of generation (evolution) of the gas as well as the rate of absorption, it follows that the

concentration of gas obtained will vary greatly from one fumigation to another. Experiments have shown that the manure fly (*Megaselia*) is killed by concentrations of between one-fourth and one-half of a milligram per liter, which can be obtained under favorable conditions at the recommended dosage (2 ounces per 1,000 cubic feet). The mushroom fly (*Sciara*) however, requires from three-fourth to 1 milligram per liter, which is too high to be safe for the crop.

Temperature seems less important than humidity and moisture. The beds should be as dry as possible, and the floor moist, but not wet, before the calcium cyanide is spread.

By light watering and proper temperature, especially in the early flushes, it is possible to force mushroom growth ahead of the development of the fly maggots, thus producing a crop in spite of the infestation. If dusting to control the adult flies is begun early, all the eggs that these flies can lay will have been laid within a short time, and oviposition reduced to a minimum thereafter. When the maggots in the beds have pupated, the spawn is free to grow without further interference.

CECIDOMYIID FLIES

The adult cecidomyiid flies are extremely small, delicate insects, about 1 millimeter, or one twenty-fifth of an inch in length, brownish and with orange abdomen. The species most common at Arlington Experiment Farm, Va., has been determined as *Mycophila fungicola* Felt. They are very inconspicuous, as they remain flat against the bedboards and usually fly only when disturbed. Those that have been observed in flight were unable to maintain their initial altitude in the absence of ascending air currents, and were able to fly only a few feet at a time. They live only a few days at most. Each female is capable of laying from three to five or more relatively large eggs. The eggs hatch into small, threadlike, legless larvae, or maggots, which rapidly mature. Mature larvae are about one-tenth of an inch in length, white, and semitransparent. A very peculiar feature in the life history of these flies is that they are "paedogenetic," i. e., able to multiply in the larval condition. Each young larvae feeds for a time until it reaches full size, becomes quiescent, the larval skin splits, and from 2 to 18 young larvae emerge, leaving the remains of the parent behind. Under favorable conditions this process may take place every 7 or 8 days. At times the larvae give rise to a thread-like form, much less robust than the parent, which is apparently better able to withstand adverse conditions. At other times bright orange forms are produced, some of which may pupate and emerge as adults, the remainder continuing to reproduce paedogenetically. All forms of larvae seem to be mutually interchangeable, but the conditions governing the production of the different forms or those governing the formation of pupae are not known.

Normally these larvae are minor pests of mushrooms, but at times they may appear in large numbers on the casing soil and mushrooms, and if sufficiently numerous may cause injury to the spawn, and to the mushrooms by eating small holes into the stems and caps. They are probably brought into the houses with the casing soil as a rule, being, in the wild state, feeders on wild fungi and molds and organic material in the soil.

Dusting is effective against the adults, but has little effect on the larvae. Other insecticides tried to date are not of much value.

Larvae on the surface of the casing soil have been successfully controlled by allowing the beds to dry out somewhat between flushes and then drenching the surface with boiling water. Playing an alcohol or gasoline blowtorch rapidly over the surface seems not to damage the spawn, and will probably kill as many larvae as the hot water. Neither of these methods will kill larvae below the top one-eighth or one-fourth inch of casing soil. Gasoline torches should be used with caution because of the danger of oil fumes causing "rose-comb" mushrooms later on.

Mites

Four species of mites are important pests of mushrooms, one very serious, two less so, and the fourth sporadic and of minor importance.

THE MUSHROOM MITE

The species *Tyroglyphus lintneri* Osb. (fig. 8) is the one most frequently found in mushroom houses in the United States. This mite feeds on almost any organic material, and is common upon cheese, dried meat, and fruits. It has been reported only from the United States and Canada. It frequently occurs in enormous numbers in mushroom plantings and is capable of completely ruining the crop. The initial infestation may be the result of the introduction of some stage of the mites into the house with the compost, or on the clothing of workers or other persons entering the houses, or on the bodies of various species of flies coming from infested houses.

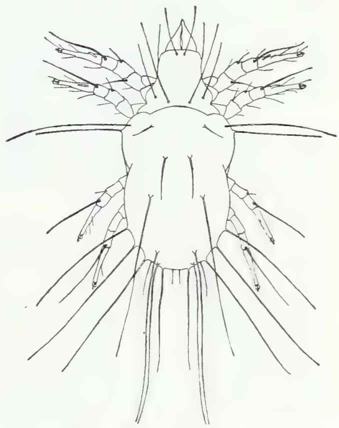

Figure 8.—Adult of a mushroom mite, *Tyroglyphus lintneri* Osb., × 100.

The mites damage mushrooms by eating holes into their caps and stems in the button stage, preventing them from developing or rendering them unmarketable, and in eating the mycelial threads in the spawn. If these mites become very numerous they may consume all the spawn and may then feed on the manure itself, reducing it practically to a mass of fine frass. Mites feed in all except the egg and hypopial stages. Mites in the mushroom beds are often overlooked, as they are very small. Unless they are very numerous the damage to the mushrooms may be slight, and the damage to the spawn is reflected only in smaller yield, which may often be attributed by the grower to other causes.

The eggs are extremely small, although rather large as compared to the parent mite. They are oval, white or yellowish, and are laid in the spawn or casing soil, or on the mushrooms. In from 8 to 14 days the egg hatches into a very small, white, six-legged larva. In another 8 or 10 days the larva molts and becomes a nymph. The

nymph is a little larger than the larva and has eight legs instead of six. After a longer period of feeding and after undergoing two more molts the nymph becomes an adult mite. At 75° F. these mites require about 2 weeks to complete their development from egg to adult, while at 55° an average of over 7 weeks is required.

At rare intervals a migrating stage or condition may occur between two of the nymphal molts, known as the hypopus. In the hypopial stage the mite is flattened, with eight legs, rudimentary mouth parts, and an area of suckers on the ventral side. Not every individual passes through this stage, and the conditions under which it is formed are not well understood. Although unable to feed, the hypopus can survive for a long time under adverse conditions. It will grasp and cling to any moving object with which it comes into contact, and is capable of being carried about by flies and gamasid mites, and on the clothing of workers in the mushroom houses. Flies have been seen that were so covered with mites in the hypopial stage that they were unable to fly. When the hypopus drops or is brushed off, it continues its development into an adult mite if it finds conditions favorable.

Prevention of infestation by the mushroom mite is the only certain means of avoiding damage to the crop. It is important that the beds go through a good heat, as the mites are nearly always present in the manure and can be controlled most effectively by killing them at this time. Control by chemicals has been attempted, but in most cases has not been successful, or only partially so.

When *Tyroglyphus* mites are numerous on the surface of the beds, flame or hot water will destroy many of them, but will not affect those in the compost. Certain growers report fair control by the use of live steam from a steam atomizer, with a little aniline added.

THE LONG-LEGGED MITE

The long-legged mite (*Linopodes antennaepes* Banks) (fig. 9) is less abundant than the mushroom mite. It is extremely difficult to control. In some places it occurs sporadically, while in others, although nearly always present, it is said to do little damage. Since it is native to this country, occurring normally under leaves and boards on the ground out of doors, it may be brought into nearly any mushroom house, and if proper conditions are present it may develop into a serious pest. The body is very minute, yellow to reddish brown, and the legs, especially the front pair, are very long and slender.

Very little is known of the life history of this mite. The minute round eggs are laid in groups in the casing soil and hatch in about 8 or 10 days into very small white larvae. These molt in 6 or 8 days into nymphs, with longer front legs than in the preceding stage. These mites have never been observed damaging spawn, and several attempts to rear them beyond the first nymphal stage on spawn have been unsuccessful, so it is probable that the activities of this species are almost entirely confined to the surface of the mushroom beds. They damage mushrooms by chewing off the feeder roots of the growing mushrooms, causing the stems to constrict at the base, and injuring or killing the developing mushrooms.

Sanitation and prevention of infestation are the best methods of avoiding damage by these mites. The mites are easily killed by heat,

having been found to succumb to 100.4° F. in one-half hour at a relative humidity of 89 percent. If the temperature along the floor does not reach this point, however, the mites in that location will recover and reinfest the beds. They are very active and are capable of crawling into cracks in the floor and walls to escape the heat.

Since these mites are found chiefly on or near the surface of the beds, the control measures recommended for cecidomyiid fly larvae should be effective against them.

RELATED SPECIES

In addition to the above-mentioned mites five other species are occasionally found in mushroom houses.

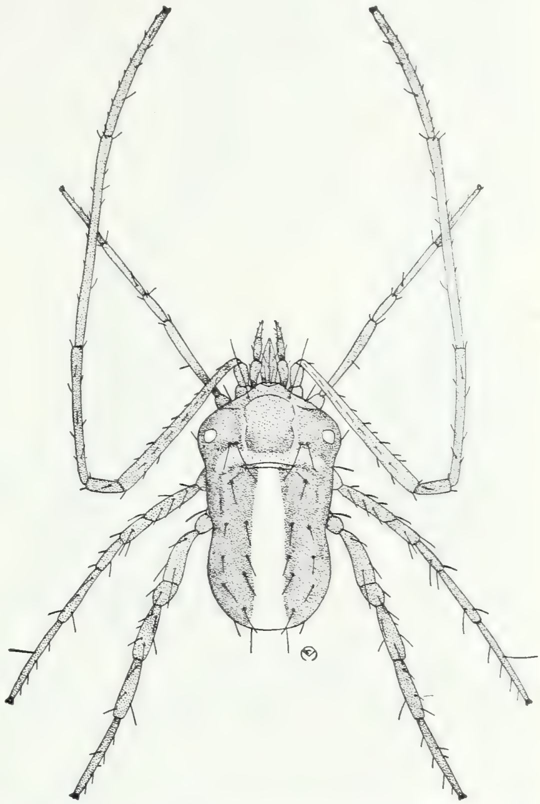

FIGURE 9.—The long-legged mite (*Linopodes antennaepes*), × 70.

Rhizoglyphus phylloxerae Riley resembles *Tyroglyphus* except that it is larger, with shorter body bristles and darker legs. It has similar habits and life history, except that the hypopial stage is very common, so the species is carried about more readily by flies and other insects. This species is common in compost heaps. A good heat after the beds are filled, and prevention of the entrance of flies into the house will do much to prevent an infestation. After they become established the spawn is usually full of them, and little can be done except to keep them from eating pits in the mushrooms themselves by close and frequent picking of the infested mushrooms.

Histiostoma sp., probably *gracilipes* Banks, is a very small mite, white, with a "warty" appearance. It feeds on both mushrooms and spawn, and apparently carries bacteria which cause the death and disintegration of mycelium and mushroom tissue. At any rate, where these mites are found the spawn or mushroom has a brown, watery, decayed appearance. Hypopi are produced in great numbers. Prevention of entry and sanitation are the only known methods of combating this mite.

Tarsonemus confusus Ewing and *T. floricolus* C. and F. are two very closely related forms of mites occurring sporadically, but

capable of doing a great deal of damage if they become established. The adult females are by far the most common, and superficially resemble the hypopi of some other mites, being oval, flattened, and brown. When examined under a powerful magnifying glass a transverse white or yellow band is visible. Little is known of the life history of these mites except that under ordinary conditions the time from egg to adult is about 10 days, and that they are parthenogenetic in the same way that honeybees are, i. e., unfertilized eggs produce males. These mites sometimes occur in enormous numbers, each mushroom on the bed bearing a thousand or more. Although found in the spawn, their tendency seems to be to work their way upward to the surface. Besides eating the mycelium the mites chew minute pits in the mushrooms, causing them to turn brown. Flame or hot water should prove effective against these mites.

Springtails

Springtails are, in general, very small, gray, blackish, or brown insects, ranging from about one sixty-fourth to one-sixteenth of an inch in length. Beneath the abdomen of each insect there is a powerful springlike appendage which, when released, is capable of hurling the insect through the air for a distance many times its own length. In a wild state springtails live normally in damp places beneath rubbish and leaves, and most of them feed upon fungi. It is probable that many of these "wild species," when once introduced into a mushroom house, might prove to be serious pests. A number of species of springtails are found frequently in mushroom beds. These include *Achorutes armatus* Nic., *Priostoma minuta* Tull., *P. simplex* Fols., *Entomobrya* sp., *Xenylla welchi* Fols., *X. humicola* (O. Fab.) Tull., *Lepidocyrtus albicans* Reut., *L. cyaneus* Tull., *L. cyaneus* var. *cinereus* Fols., and *L. lanuginosus* (Gmel.). All these are capable of doing damage to spawn and mushrooms throughout the season. Two of these springtails are shown in figure 10, *A* and *B*.

Some growers have the idea that the presence of springtails in the houses is to be desired; in other words, that springtails in numbers are an indication of a good crop. This is possibly true to the extent that conditions favorable to springtails also favor the growth of mushrooms, but it is also true that these same favorable conditions may allow the springtails to multiply fast enough to reduce the crop materially. Springtails inflict damage by eating the spawn and by chewing holes in the stems and caps of the mushrooms. These pests are so easily overlooked that the grower frequently attributes the reduction in yield to some other cause.

The life history of these creatures is very simple. The minute spherical eggs are laid in groups in the compost or spawn. They hatch in about 10 days into minute replicas of the adults except for their lighter color. After a period of growth and several molts, these become capable of reproduction. Almost from the moment they hatch from the egg they are capable of feeding upon and damaging spawn and mushrooms.

Springtails are usually brought into the houses with the compost, but may enter later through cracks. For this reason it is important that the surroundings of the mushroom houses be clean and

free from rubbish so as to offer as little refuge as possible to these pests. Although they are capable of withstanding intense cold, they are easily killed by heat. In the case of *Lepidocyrtus lanuginosus* Gmel., a springtail found doing damage in commercial houses in Ohio, it has been determined that heating infested mushroom houses to a temperature of approximately 104° F. for 10 minutes will kill the majority, if not all, of them. For this reason it is important that the houses go through a good heat, and that the bottom beds and floor be also well heated. Otherwise springtails escaping from the upper beds will survive on the floor and bottom beds and later reinfest the entire house.

As in the case of the mushroom mite, springtails in the beds are very difficult to control, since insecticides do not penetrate the beds well, and only the insects on the surface are killed. Sometimes by lightly spraying the beds with water 4 or 5 hours before treatment the springtails may be brought to the surface, and more of them killed by subsequent applications of insecticides.

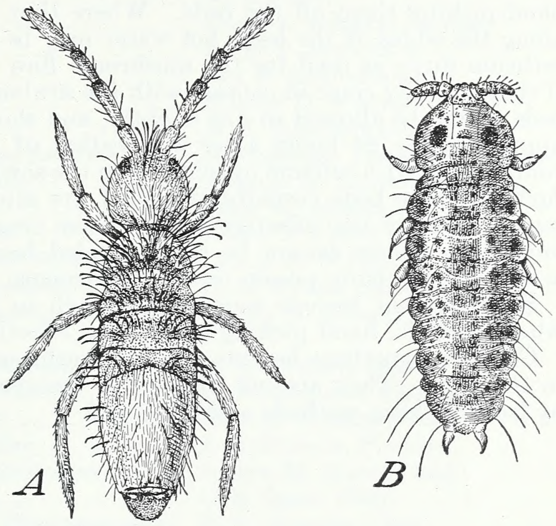

FIGURE 10.—Two species of springtails that attack mushrooms: *A*, *Lepidocyrtus lanuginosus*, × 30; *B*, *Achorutes armatus*, × 60.

Fumigation with calcium cyanide at the rate of 2 ounces per 1,000 cubic feet of air space is also fairly effective.

Some species of springtails have a habit of congregating in mushroom houses at certain times in enormous numbers, looking like piles of gray powder in the aisles. Whenever springtails are found congregating in the aisles of a house they should be swept up and burned or otherwise destroyed.

A 3-percent nicotine-lime dust is effective against springtails if it comes into actual contact with them.

Springtails are very active, and during the course of the season a great number will find their way to the floor of the house. Bands of sticky tree-banding material or nicotine about the bed supports will prevent many of these from climbing up into the beds again.

Miscellaneous Pests

A small mycetophagid beetle, *Litargus balteatus* Lec., has become a pest, during the last few years, in at least two mushroom establishments in the West. Very little is known of this insect or of methods for controlling it.

The meal moth (*Pyralis farinalis* (L.)) was found feeding in the spawn on one occasion. The adults may be controlled by pyrethrum dust mixtures and probably would never be of importance in houses that are dusted regularly for fly control.

Sowbugs, also known as "pillbugs" and "wood lice," are elongate, convex, slate-gray crustaceans, with seven pairs of legs. Fully grown specimens may be one-half of an inch in length. They occasionally become numerous enough in mushroom beds to cause some damage by eating holes in the buttons and in the caps of matured mushrooms. In a cellar or other small area it is possible to control sowbugs by hand-picking them off the beds. Where they congregate in clusters along the edges of the beds, hot water may be poured on them. Pyrethrum dusts as used for the mushroom flies will give some control if they actually come in contact with the sowbugs. In using dusts, the beds should be allowed to dry slightly, and should not be watered for approximately 24 hours after application of the insecticide. Light fumigations with calcium cyanide when the sowbugs are feeding on the surface of the beds (usually at night) are said to be effective. Poisoned baits are also effective against these creatures, but their use in mushroom houses cannot be recommended because of the danger of accidentally getting poison on the mushrooms.

Slugs seldom become numerous enough to be of importance, but where they do, hand picking is the most effective remedy.

Crickets sometimes become pests in mushroom beds by eating holes in the caps. They are not difficult to discover and can be collected by hand-picking methods and destroyed.

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U. S. GOVERNMENT PRINTING OFFICE: 1941

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